A Low-Cost, Non-Invasive, Continuous Bilirubin Monitor for Neonates

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Discussion, Discovery, and Dissemination Event
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SACRAMENTO STATE
COLLEGE OF ENGINEERING & COMPUTER SCIENCE

PROBLEM STATEMENT

Hyperbilirubinemia, the excess build-up of bilirubin in the blood, can occur in neonates, especially when born prematurely. Severe hyperbilirubinemia can lead to permanent brain damage and even death. Phototherapy, placing the neonate under blue light, can reduce bilirubin level. Current non-invasive bilirubin monitors do not provide useful measurements during phototherapy, and blood for laboratory analysis must be drawn by a painful "heel-stick." A non-invasive bilirubin monitor is needed to track progress during phototherapy.

BACKGROUND

As reported at the 2020 Discussion, Discovery, and Dissemination (D3) Event, Sacramento State faculty and students are developing a novel, low-cost, non-invasive bilirubin monitor for neonates. Progress is being made through international collaboration with Brazilian faculty members and students, by engineering senior design students, and by master's thesis and project work. Most recently, EEE graduate student Emmanuel Dupart completed his master's project on this topic in summer, 2020. Figure 1 shows Emmanuel presenting his work at a system-wide California State University conference in January, 2020.

Presented here at the 2021 D3 Event is an update on progress on the bilirubin project during the COVID-19 pandemic.

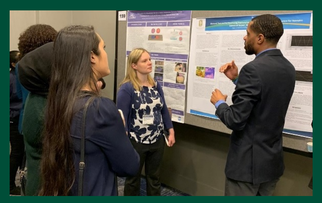

Figure 1. Sac State EEE graduate student Emmanuel Dupart presenting his master's project work at the 32nd CSU Annual Biotechnology Symposium in Santa Clara, CA, January 20, 2020.

SUMMARY OF WORK

Bilirubin in body tissue absorbs blue light, so it can be detected noninvasively by shining a blue light through the tissue and measuring how much comes out the other side. Hemoglobin in the tissue also absorbs blue light and interferes with the detection of bilirubin. Hemoglobin also absorbs green light, but bilirubin does not. So, hemoglobin absorption of green light can be used to "subtract out" its absorption of blue light, thus revealing the effect of bilirubin.

The pandemic has stopped our campus work in the RVR 5027 lab, so I am continuing the development of the bilirubin monitor at home. I use my finger to stand in for a neonate's foot. Figure 2 shows my finger with blue and green light-emitting diodes (LEDs) attached to the ball of the finger (left), a photodetector attached to the fingernail (center), and a plastic clip-on cover secured by a rubber band (right). Figure 3 shows electronic circuitry I built (right foreground) and a USB-6009 module (National Instruments, Austin, TX) (left foreground) to turn on and off the LEDs and operate the photodetector. I designed a LabVIEW (National Instruments) virtual instrument (VI) to interface with the USB-6009 module to control the operation of the LEDs and acquire and process the photodetector output. Figure 4 shows the VI front panel. In the top chart, the upper traces show the pulsatile green and blue LED photodetector outputs, and the lower traces show measures of green and blue absorbance.

Figure 2. My finger with attached blue and green LEDs (left), photodetector (center), and plastic cover secured by a rubber band.

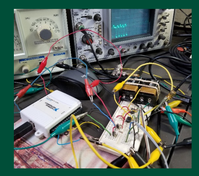

Figure 3. Electronic circuitry (right foreground) and USB-6009 module (left foreground).

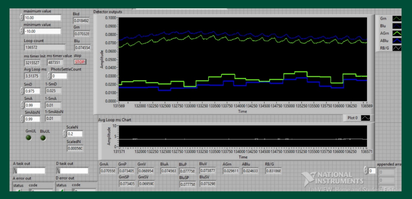

Figure 4. (left) Front panel of LabVIEW VI controlling the green and blue LEDs and acquiring and processing the photodetector output. In the upper chart, the top two traces show the pulsatile photodetector outputs for the green and blue LEDs, and the lower two traces show measures of absorbance for the green and blue LEDs.

NEXT STEPS

As I continue to develop the bilirubin monitor hardware and software at home during the pandemic, my aim is a robust, portable monitor that provides consistent results on my finger. As we become freed from the pandemic, and Sac State students and faculty members can collaborate on campus in the lab again, we will continue monitor development, including human subjects studies with UC Davis clinicians on subjects with known blood bilirubin levels. Our ultimate goal is a small, low-cost, non-invasive bilirubin monitor for neonates. Figure 5 illustrates how the monitor might be attached to a neonate's foot.

Figure 5. Illustration of how a non-invasive bilirubin monitor may be attached to a neonate's foot.